CHAPTER 2
FUNDAMENTALS OF RADIOLOGIC SCIENCE

STANDARD UNITS OF MEASUREMENT

Physics
- The study of interactions of matter & energy

Three Base Quantities
- Mass, Length & Time

Secondary/Derived Quantities
- The combination of one or more base quantities

Special Quantities
- Exposure, Dose, Equivalent Dose & Radioactivity

IBWM
- International Bureau of Weights & Measures

Length
- It is based on speed of light
- *SI Unit:* meter (m)
- *Platinum-Iridium Bar:* represents the standard unit of length
- *Redefinition*: wavelength of orange light emitted from an isotope of krypton-86
- *One Meter:* distance traveled by light in 1/299,792,468

Mass
- *One Kilogram*: mass of 1000 cm^3 of water at 4^o C
- *SI Unit:* kilogram (kg)
- *Platinum-Iridium Cylinder:* represents the standard unit of mass
- *Units of Weight*: Newton (N) & pounds (lb)

Time
- It is based on the vibration of atoms of cesium
- *Original Definition:* based on rotation of Earth on its axis (mean solar day)
- *Redefinition:* a certain fraction of the tropical year 1900
- *Recent Definition:* measured by an atomic clock

Measurement
- It has a magnitude & a unit

Four Systems of Units
- MKS
- CGS
- British
- SI

SPECIAL QUANTITIES OF RADIOLOGIC SCIENCE & THEIR UNITS

Radiographic Quantities	Special Units	SI
Exposure	C/kg	Air kerma (Gy_a)
Dose	J/kg	Gray (Gy_t)
Equivalent Dose	J/kg	Sievert (Sv)
Radioactivity	s^{-1}	Becquerel (Bq)

The same system of units must always be used when one is working on problem or reporting answers!

MECHANICS

Mechanics
- The segment of physics that deals with motion at rest (*statics*) & objects in motion (*dynamics*)

Velocity (V)
- It is sometimes called *speed*
- The rate of change of its position with time
- *Formula:* V = d/t
  - d = distance
  - t = time
- *SI Unit:* m/s
- *British Unit:* ft/s

Velocity of Light
- *Symbol:* c
- $c = 3x10^8$ m/s or $1.86x10^5$ mi/s

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Average Velocity
- *Symbol:* $\bar{v}$
- *Formula:* $\bar{v} = (V_f + V_o)/2$
  - V_f = final velocity
  - V_o = initial velocity
- *SI Unit:* m/s
- *British Unit:* ft/s

Acceleration
- The rate of change of velocity with time
- *Symbol:* a
- *Formula:* $a = (V_f - V_o)/t$
  - V_f = final velocity
  - V_o = initial velocity
  - t = time
- *SI Unit:* m/s^2
- *British Unit:* ft/s^2
- *Constant Velocity*: zero acceleration

Isaac Newton (1686)
- He presented the fundamental laws of motion

Newton's First Law: Inertia
- A body will remain at rest or will continue to move with constant velocity in a straight line unless acted on by an external force

Inertia
- The property of matter that acts to resist a change in its state of motion

Newton's Second Law: Force
- The force (F) that acts on an object is equal to the mass (m) of the object multiplied by the acceleration (a) produced

Force
- A push or pull on an object
- *Symbol:* F
- *Formula:* F = ma
  - m = mass
  - a = acceleration
- *SI Unit:* newton (N)
- *British Unit:* pounds (lb)

Newton's Third Law: Action/Reaction
- For every action, there's an equal & opposite reaction

Weight
- A force on a body caused by the pull of gravity on it
- *Symbol:* Wt
- *Formula:* Wt = mg
  - m = mass
  - g = acceleration due to gravity
- *SI Units:* N or lb

Acceleration Due to Gravity
- *Symbol:* g
- *Constant in SI Unit:* $9.8\ m/s^2$
- *Constant in British Unit:* $32\ ft/s^2$

Weight is the product of mass & the acceleration of gravity on earth: 1 lb = 4.5 N!

Momentum
- The product of mass of an object & its velocity
- *Symbol:* p
- *Formula:* p = mv
  - m = mass
  - V = velocity
- SI Unit: kg-m/s
- *British Unit:* lb-ft/s
- Total p *before interaction* = Total p *after interaction*

Work
- The force applied times the distance
- *Symbol:* W
- *Formula:* W = Fd
  - F = force
  - d = distance
- *SI Unit:* J
- *British Unit:* ft/lb

Power
- The rate of doing work
- The quotient of work over time
- *Symbol:* P

- *Formula:* P = Work/t = Fd/t
  - F = force
  - d = distance
  - t = time
- *SI Units:* J/s or W
- *British Unit:* hp
- *One hp*: 746 W

Energy
- The ability to do work

Law of Conservation of Energy
- States that energy may be transformed from one form to another but it cannot be created or destroyed

Two Forms of Mechanical Energy
- Kinetic & Potential Energy

Kinetic Energy
- The energy associated with the motion of an object
- *Symbol:* KE
- *Formula:* $KE = \frac{1}{2}mv^2$
  - m = mass
  - v^2 = velocity squared
- *SI Unit:* J
- *British Unit:* ft-lb

Potential Energy
- The stored energy of position or configuration
- *Symbol:* PE
- *Formula:* PE = mgh
  - m = mass
  - g = acceleration due to gravity
  - h = height
- *SI Unit:* J
- *British Unit:* ft-lb

Heat
- The KE of the random motion of molecules
- *Unit:* calorie

Calorie
- The heat necessary to raise the temperature of 1 g of water through 1^o C

Three Ways of Heat Transfer
- Conduction, Convection & Radiation

Conduction
- The transfer of heat through a material by touching

Convection
- The mechanical transfer of "hot" molecules in a gas or liquid from one place to another

Thermal Radiation
- The transfer of heat by the emission of infrared radiation
- An x-ray tube cools primarily by radiation

Temperature
- It is measured with a thermometer
- *3 Scales:* Celsius, Kelvin & Fahrenheit

Converting Fahrenheit (F) to Celsius (C)
- *Formula:* $T_c = 5/9(T_f - 32)$
  - T_c = temperature in celsius
  - T_f = temperature in fahrenheit

Converting Celsius to Fahrenheit
- *Formula:* $T_f = 9/5(T_c) + 32$

Converting Celsius to Kelvin (K)
- *Formula:* $K = T_c + 273$
  - K = temperature in Kelvin

Approximate Temperature Conversion
- From ^oF to ^oC: subtract 30 & divide by 2
- From ^oC to ^oF: Double, then add 30

Cryogens
- The cooling agents used in MRI
- *Liquid Nitrogen:* boils at 77 K
- *Liquid Helium:* boils at 4 K

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MATHEMATICS FOR RADIOLOGIC SCIENCE

Fractions
- The quotient of two numbers
- *x/y:* numerator/denominator

Proper Fraction
- The quotient is less than one

Improper Fraction
- The quotient is greater than one

Adding/Subtracting Fractions
- Find a common denominator then add or subtract
- $x/y + a/b = xb/yb + ay/yb = (xb + ay)/yb$

Multiplying Fractions
- Simply multiply numerator & denominator
- $(x/y) \times (a/b) = xa/yb$

Dividing Fractions
- Invert the second fraction & multiply
- $x/y \div a/b = (x/y) \times (b/a) = xb/ya$

Ratio
- It expresses the mathematical relationship between two similar quantities

In addition & subtraction, round to the same number of decimal places as the entry with the least number of digits to the right of the decimal point!

In multiplication & division, round to the same number of digits as the entry with the least number of significant digits!

Three Principal Rules of Algebra
- *First Rule:* when an unknown *x* is multiplied by a number, divide both sides of the equation by that number
  Step 1: $ax = c$
  Step 2: $ax/a = c/a$
  Step 3: $x = c/a$
- *Second Rule:* when numbers are added to an unknown *x*, subtract that number from both sides of the equation
  Step 1: $x + a = b$
  Step 2: $x + a - a = b - a$
  Step 3: $x = b - a$
- *Third Rule:* when an equation is presented in the form of a proportion, cross-multiply & then solve for the unknown *x*
  Step 1: $x/a = b/c$ (cross-multiplication)
  Step 2: $cx = ab$
  Step 3: $x = ab/c$

Proportion
- It expresses the equality of two ratios

Decimal System
- System of numbers that is based on multiples of 10

Decimal to Exponential Form
- If there are digits to the left of the decimal point, the exponent will be positive
- If there are no nonzero digits to the left of the decimal point, the exponent will be negative

Planck's Constant
- *Symbol:* h
- *Constant:*
  - 4.15×10^{-15} Ev-s
  - 6.63×10^{-34} Js

Rules of Exponents
- *Multiplication:* $10^x \times 10^y = 10^{(x+y)}$
- *Division:* $10^x \div 10^y = 10^{(x-y)}$
- *Raising to a Power:* $(10^x)^y = 10^{xy}$
- *Inverse:* $10^{-x} = 1/10^x$
- *Unity:* $10^0 = 1$

Graphing
- It is based on two axes: x-axis & y-axis

Origin
- The point where the two axes meet

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Ordered Pairs
- (x-axis, y-axis)

Radiologic Units
- Roentgen, Rad, Rem, & Curie

Roentgen/Exposure
- The unit of radiation exposure or intensity
- It is defined as a unit of radiation quantity (1928)
- Applies only to x-rays & gamma rays & their interaction with air
- *Symbol:* R
- *SI Unit:* air kerma (Gy_a)
    - Adoption of *Wagner/Archer Method*
- *1 R:* 2.08 x 10^8 ip/cm^3 of air
- *1 R:* 2.58 x 10^{-4} C/kg (official)

Rad/Dose
- The unit of radiation absorbed dose
- The quantity of radiation received by the patient
- It is used for any type of ionizing radiation & exposed matter, not just air
- *Symbol:* rad
- *SI Unit:* gray (Gy_t)
- *Special Unit:* J/kg
- *1 Rad:* 100 erg/g or 10^{-2} Gy_t
- *Erg (J):* a unit of energy

Rem/Equivalent Dose
- The unit of occupational radiation exposure
- It is used to expressed the quantity of radiation received by radiation workers & populations
- *Symbol:* rem
- *SI Unit:* Sievert (Sv)
- *Special Unit:* J/kg
- *Application:* occupational radiation monitors

Curie (Ci/Bq)
- A unit of radioactivity
- The unit of quantity of radioactive material
- *Symbol:* Ci
- *SI Unit:* Becquerel (Bq)
- *Special Unit:* s^{-1}
- *1 Ci:* 3.7 x 10^{10} nuclei disintegration per second (Bq)

TERMINOLOGY FOR RADIOLOGIC SCIENCE

STANDARD SCIENTIFIC & ENGINEERING PREFIXES

Multiple	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	**tera**	**T**
10^{9}	**giga**	**G**
10^{6}	**mega**	**M**
10^{3}	**kilo**	**k**
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	**centi**	**c**
10^{-3}	**milli**	**m**
10^{-6}	**micro**	**μ**
10^{-9}	**nano**	**n**
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Diagnostic radiology is concerned primarily with x-rays. We may consider: 1 R = 1 rad = 1 rem or 1 mGy_a = 1 mGy_t = 1 mSv)!